**REPUBLIC OF MOLDOVA**

# SYSTEM RULES AND REGULATIONS

**Regulatory Development**
**and**
**Power Market Operations**

**Moldova Energy Sector Reform**
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Republic of Moldova

**Moldova Power Market**

# SYSTEM RULES AND REGULATIONS

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# SYSTEM RULES AND REGULATIONS

## 1. GENERAL PROVISIONS AND TERMINOLOGY

### 1.1 General Provisions

The Electric Power Grid (EPG) of Moldova is a highly automated, permanently developing technological system, comprised of electric power plants operating in parallel, the integrated high voltage transmitting network (UHVTN), the central dispatching (CD Moldtranselectro) and distribution networks (DN), which are connected to each other by a common regime (schedule) and the integrated system of technological (dispatching and automatic) control.

The EPG of Moldova and the infrastructure providing the preparation of production, functioning and development of the Moldova EPG (transport repairing and construction enterprises, designing and research institutes) is an industry branch, i.e., electric power engineering.
The main purposes of the Moldova EPG are:

- providing reliable supply of quality electric and heat energy to customers; and
- providing a technological space for efficient exchange of electric power between its producers and consumers.

### 1.2 Terminology

| | |
|---|---|
| Power balance (of electric power) | Equality of generated and received power (on the one hand0 and power (electric power) consumed and delivered (on the other hand) for a technological (or economic) object |
| Dispatcher's training facilities | A complete set of hardware and software designed for training of dispatching personnel |
| Dispatching control | On-line (*operative*) control |
| Transmission capacity reserve | Additional active power value which can be transmitted through a specific electric power line (with a specific section) with a specific regime |

| | |
|---|---|
| Installed capacity of a set-up (electric power plant, energy system) | A capacity with which a set0up is able to operate for a long time without overloading, in accordance with its specifications |
| Available capacity of a set-up | Installed capacity reduced by restriction values |
| Operating capacity of a set-up | Maximum capacity which can be used during the period in question without overloading, taking account of existing restrictions and temporarily non-used capacity |
| Connected capacity | A sum of generated power and rotating reserve |
| Production capacity | Installed capacity reduced due equipment stoppage for routine-and-prevention maintenance, technical upgrading and reconstruction |
| Non-used operationally | A capacity decommissioned for a long time period due to repairing |
| Power transfer in section, at steady regimes, normal regimes | Tolerable for a long time period |
| Forced (during operation) | Increased loads for a finite time period in order to prevent consumer restrictions, hydro resource losses, etc |
| Emergency permissible | Increased loads for a short time period |
| Emergency | Non- permissible for a short time period |
| Post- emergency | After disconnection of fault conditions |
| Increased (in designing) | Increased due to unfavorable combination of electric power plants' equipment in the maximum and minimum loading regimes (a total duration not more than 10% in a year) |
| Regime planning | |
| long-term | for a month, a year |
| short-term | for a day, a week |

| | |
|---|---|
| Electric power consumption | |
| Maximum | Maximum value of power consumed by a set-up (or energy system) for a definite time period |
| Schedule | Value of power consumed by a set-up (or energy system) for each hour of a definite time period |
| Electric Power Grid transmission capability | Active power value which can be transmitted through a specify electric power line or a section (several electric power lines connected into a common electric power grid) |
| Electric regime | Energy system status which is characterized by regime parameters values |
| Steady electric regime | Is characterized by parameters value constancy |
| Transition electric regime | Since initial disturbance till completion of electromagnetic and electromechanical processes caused by it (taking account of turbine rotation rate regulating systems' operation) |
| Reserve of generating | Additional generating capacity, which can be implemented *(realized)* within a definite time period |
| Operational reserve | A difference between operating capacity and load at the given time |
| Cold reserve | Operating capacity of a set-up which is not connected to a grid and can be implemented *(realized)* within tens of minutes, hours, if necessary |
| Rotating (connected) reserve | Reserve capacity of an operating set-up |
| Hot reserve | Reserve capacity, which can be used in a few minutes |
| Nondelivered reserve | Restricted by a transmitting capacity of an electric power grid |

| | |
|---|---|
| Repairs of basic energy facilities | |
| Maintenance | up to 4 days |
| routine repair | 4 to 15 days |
| medium repair | 20 to 30 days |
| Overhaul | 40 to 90 days |
| Nonscheduled (forced, emergency, urgent) conservation | Decommissioning of operating equipment of low efficiency mainly, for a long time period; time for commissioning of the conserved set-up may be several days |
| Electric circuit diagram | Circuit diagram of equipment connections |
| Normal | for a normal regime, when all the equipment is connected for operation |
| Repair | when a part of equipment is put into reserve or on repair |
| Technological information | Information on the grid electric circuit diagram and parameters of its regimes |
| Production preparation | Preparation of the energy system operation regime, which provider reliable electric power supply of all the consumers with quality energy and efficient operation of corresponding economic objects (enterprises) |
| Technological control | Control of technological process of electric power production |
| Automatic control | Automatic control of electric power production technological process without an intervention of on-duty personnel |
| On-line technological (dispatching) control | Control of technological process according to commands of managing personnel |

| | |
|---|---|
| Electric connection | An assembly of grid elements connecting two parts of the EPG |
| Electric interface | An assembly of elements of one or several connection, which being disconnected could completely separate the EPG into two isolated parts |
| Electric power system, EPG | A complex of jointly (in-parallel) operating electric power plants and grids, which are related by a common regime and unified centralized dispatching control |
| Energy production | Processes of energy generation, transmission and distribution |

# 2. DISPATCH CONTROL

## 2.1 Structure and Basic Principles

The EPG dispatching control system is based on the following principles:

- separation of dispatching and general economic function, providing an independence of the dispatching control system (with its function) from the administrative and economic management of energy companies;
- two-level hierarchic organization of the system with direct subordination of on-duty personnel of each enterprise (the electric power grid, district grids) to the central dispatching control personnel ;
- providing each enterprise personnel with maximum independence in implementation of all operative functions, which do not need intervention of the on-duty manager of the central dispatching control;
- distinct separation of functions and responsibility of the on-duty personnel of the both levels of control in introducing of normal regimes and liquidation of emergency situations; and
- strict dispatching discipline

The Central Dispatching Control is organized in accordance with the Ruler of Technical Operation of electric power plants and grid, which specified an organizational structure tasks and functions of the dispatching control system.

The control of the EPG operation is subject to one goal to provide the most efficient operation of the EPG is a whole with reasonable spending of energy resources and meeting of energy supply reliability and energy quality requirements.

The EPG dispatching control task complexity specifies a necessity to decompose this complex task into a number of more simple interrelating tasks, which are to be resolved at all the levels of the dispatching control system.

A decomposition with respect to time means a decomposition of a common control task, which is resolving at each level of the territorial hierarchy, into tasks related to four different control levels:

- long-term planning of regimes for a term of one month, one year;
- short-term planning of regimes for a term of one day, one week;
- on-line control of current regimes, which is carried out by on-duty personnel; and
- automatic control of normal and emergency regime in the course of technological processes.

The following are implement on a supreme level of time hierarchy:

- forecasting of energy consumption and specific load schedules;
- development of capacity and electric power balance;
- optimization of energy resource usage plans and equipment overhaul timing;
- development of schemes and regimes for specific seasons (maximum at autumn-winter, flooding period, etc.), as well as in connection of new objects commissioning;
- solving of the entire complex of tasks for electric power supply reliability and energy quality improvement, introduction and improvement of dispatching control facilities and normal emergency regimes automatic control system; and
- drafting of dispatching instruction.

The long-term plans are correct regularly with changing and revising of the EPG conditions (consumption level, hydro resources availability, fuel competition, etc.). The long-term planning results play the role of basic restrictions which shall be imposed on short-term plans (weekly or daily rates of hydro resources, repair capacity, etc.). Short-term plans are optimized taking the mentioned restrictions into account, based on more complete and accurate information about operation conditions in this control cycle. When developing a short-term regime a number of restrictions, related to energy reliability and quality requirements, is to be revised.

An operative control (carrying out of a current regime by on-duty personnel) is implemented according to daily schedules, when deviations from the schedule (in consumed power, equipment conditions, etc.) occurred a necessary correction of the regime is made to provide reliability quality and economical efficiency requirements (bringing the regime to optimum conditions).

The lowest time level is an automatic control level, which is implemented by centralized and local (decentralized) systems and devices of regime's automatic control, relay protection and autifailure automatic equipment, etc.

## 2.2 Operating Regimes

The EPG can operate in various regimes (normal, increased, emergency and post-emergency). Different tasks are resolved in each of them, an extent of automatic control and allocation of duties among on-duty personnel are also different:

| Regime | Characteristics |
|---|---|
| Normal | Implementation of established requirements of electric power reliability and quality |
| Increased (forced) | Restriction are present. Some requirements of electric power reliability and quality are reduced. Emergency occurrence probability is increased. |
| Emergency | It shall be liquidated by means of protection and automatic equipment. In a number of situations it requires urgent actions of the on-duty personnel. |
| Post-emergency | The electric power system comes to it after emergency regime. Often it is an increased one and causes a necessity of the personnel intervention to restrict duration |

## 2.3 Supervision and Control

The Rules and Regulations in force require that all the elements of the electric power system (equipment, hardware, automatic devices and control facilities)are operative control, and dispatchers and senior on-duty personnel of various control levels are responsible for them.

The term "dispatching control" means a type of operative subordination, where operations with this or that equipment of an electric power system are only carried out by command of a corresponding dispatcher (senior on-duty personnel), who is responsible for it. A dispatcher control on-line the equipment which requires a coordination of a subordinated on-duty personnel actions.

The term "dispatching control" means a type of operative subordination, where operations with this or that equipment of an electric power system are carried out with permission of a corresponding dispatcher who is responsible for it.

Each element of an electric power system may be included into the responsibility of on-duty manager not only of one level, but of several on-duty managers of one or several levels. Allocation of equipment, automation and control facilities among territorial hierarchy levels according to on-duty control types characterizes not only control function between the territorial hierarchy levels based on time level of on-duty control, but defines to a great extent function allocation at various time levels.

All the equipment of the electric power system, which provide production and electric power distribution, is included into the responsibility of the electric power system's on-duty dispatcher or on-duty personnel directly subordinated to him (electric power plants' shift heads, electric and heat grids' dispatchers, substation' on-duty personnel, etc.).

The electric power system's dispatcher controls on-line the basic equipment, operations with which require a coordination of energy enterprises' (energy object) on-duty personnel action or matching changes in relay protection and automatic equipment of several object.

The on-duty dispatcher of the central dispatching control in responsible for a total operating capacity and capacity reserve of the electric power system, electric power plants and high-capacity units, intersystem connection and objects of the basic grids, which affect the electric power system's regime.

A principle of operative subordination is extended not only on basic equipment and hardware, but on relay protection corresponding objects, linear and Fault Protection equipment normal regime automatic control facilities and systems, as well as on dispatching and technological control facilities which are used by on-duty personnel.

Electric power system's on-duty dispatchers and senior on-duty managers. Equipment involved in on-line control of a corresponding link *(level)* dispatcher cannot be put out of operation or reserve, as well as put into operation without permission or instruction of the dispatcher. Instruction of energy objects' and electric power system's manager on issues included into the competence of dispatchers may be only fulfilled by the on-duty personnel with permission of the on-duty manager of higher link *(level)*.

The EPG Central Dispatching Control controls the EPG operations and permanently regulates the EPG regimes all day around.

The dispatching control personnel controls the main electric power grid regimes according to voltage. The EPG Central Dispatching Control dispatchers maintain voltage levels at corresponding points of the basic electric power grid, which are specified by the Regulations.

When there is a temporary deficiency in capacity or electric power in the EPG them the EPG Central Dispatching Control defines load or electric consumption restriction and apprise them with the Energy Commission and the Central Dispatching Control dispatcher instruct grids' dispatchers on introduction of restrictions.

The Supreme level of operative control (the EPG Central Dispatching Control) develops and approves basic instruction on effecting regimes and operative control, which are obligatory for energy enterprises' on-duty personnel.

# 3. DEVELOPMENT OF THE MOLDOVAN EPG

## 3.1 Design Cycles

The Moldovan EPG development designing includes:

- carrying out of a complete cycle of out-of-stage designing on the electric power system and its operation and control facilities development for 15 to 20 and 5 to 10 years once in 5 years;
- periodic corrections of the mentioned activity in the course of initial data revising; and
- development of energy and electric power grid sections, included into the out-of-stage designing for individual issues of electric power engineering development (location of hydro power plants, electric power supply to towns, etc.), as well as included into electric power plants and large grid objects designing.

## 3.2 Development of Electric Grid

The necessary putting of capacities at power plants into operation is dictated by conditions requiring to compensate load and to setup required capacity reserves; a necessity for dismantling of obsolete and wearied out (which is not subject to upgrading) equipment is being taken into account.

### 3.2.1. Capacity Balance

Capacity balance is drafted for a period of the winter annual load maximum.
Available capacity of electric power plants, which is account in the input part of capacity balance for a annual maximum load period, is determined according to a total installed capacity minus existing restrictions. The capacity of new equipment's model samples, to be commissioned in the accounting year and serial units to be commissioned in the IV quarter of the same year ( restriction due to non complete putting of commissioning equipment into operation).

Restrictions take account of available capacity reduction due to capacity output restrictions, mismatching of separate elements of power plants, lack of thermal load (for backpressure turbines), steam take off increase, hydropower plant pressure reduction or hydropower plant used capacity reduction due meeting non-energy customers' needs and so on.

Hydropower plants capacity reduction in low-water year is accounted in the balance separately as "non-used capacity".

When calculating the EPG capacity balance the planned capacity flows are taken into account: input of capacities into the electric power system is accounted in the input part of its balance, and capacity deliverable in the output part. The planned capacity exchange, as well as the calculated capacity reserve is determined according to the capacity balance data and the EPG reliability provision terms. When determining a deliverable part of the EPG capacity balance its absolute ("non regular") annual maximum load is assumed.

Schedule of an average day in the most loaded decide of winter period (usually for December) is considered as a designed maximum EPG load schedule. This schedule's load maximum is determined by adding the $_{nonreg}$ value to the regular value:

$$_{nonreg} = 0.01\ P_m + 1.24\ P_m$$

where

$P_m$ is the regular maximum, MW.

### 3.2.2. Capacity Reserves

Designed capacity reserved is determined taking account of transmitting capacity of system-forming grids and in general case is a sum of:

- a repair reserve, which is necessary to compensate capacity reduction occurred due to scheduled repairs of equipment;
- a designed operative reserve, which includes two components - an emergency reserve restoring emergency capacity reduction due to equipment failure, and a load reserve compensating unforeseen of a designed (non regular) maximum from a designed deviations value, - which are to be determined simultaneously; and
- an economic reserve designated to compensate the balance distortions caused advanced development of individual broaches of the national economy.

A repair reserve is determined separately for routine repairs and overhauls (including medium ones) of the basic equipment.

Reserve size for routine repairs carried out during the maximum periods is assumed as a percentage of available capacity for each type of power plant equipment: it is 2% for TEPP and KEPP with transversal connections and less-than-100 MW units, 3.5% for units of 100 to 135 MW capacity; 4 to 4.5% for TEPP and KEPP with electric power units of 150 to 200 MW capacity.

Reserve for routine repairs HPP units during the winter maximum load period is not planned.

Overhauls and medium repairs of the equipment, as a rule, are carried out during a seasonal load drop period. When a seasonal drop is not enough, then the necessary additional reserve for the winter maximum load period is to be determined proceeding from established periodicity and duration of overhauls (including medium ones) based on the analysis of an annual load schedule. When more accurate data are absent, then the following data of an average annual duration of electric power plant equipment maintenance during overhauls and medium repairs may be accepted: 4.1% of a calendar time for HPP's units; 2.5% for TEPP and KEPP with transversal connections and less-than-100 MW units, 3.5% for units of 100 to 135 MW capacity; 4.5 to 5% for TEPP and KEPP with electric power units of 150 to 200 MW capacity.

In order to upgrade the equipment exceeded its service life, which requires decommissioning of this equipment to be repaired during a long time period, an additional repair reserve is planned.

The joint determination of a design operative reserve (its size and location) and transmitting capacities of a system-forming connections is carried out based on the optimizing calculations of minimum reduced expenses, taking account of mathematical expectation of damage caused by non-reliable electric power supply. These calculations take the following into account:

- A structure of generating capacity and reliability indices of various-type units; and
- Energy consumption regimes and presence of random load deviations from the planned values.

In "Governing Instructions and Regulations on Designing of Energy System Development" the reliability indices recommended to be used for various-type units – mean statistical values of relatively long duration of emergency downtime - are given. These indices are: 0.005 for HPP units; 0.02 for the TEPP with transversal connections; 0.045 for the serial energy producing units (more than 5 years after the first serial units manufacturing dates) with a capacity of 150 to 200 MW.

A total reserve of the EPG capacity, including repair and operative reserves, as well as the national economy reserve, which is assumed to be 1% of the maximum load for the perspective of 10 years and 2% for more distant perspectives, shall not be less than 17% of a combined load maximum of the EPG.

### 3.2.3. Electric Energy Balance

The balance of electric energy, with checking a possibility to produce the required amount of electric power, revealing fuel needs and determining energy transfers, is drafted based on the EPG capacity balance.

### 3.2.4. Fuel Reserves

In order to implement the planned electric power balance reliably, the provision of fuel reserves is required, together with the judicious use of hydroresources.

### 3.2.5. Circuit Design and Parameters of Basic Grids

When selecting a circuit design and parameters of basic grids of the electric power system, conditions for supplying of individual load nodes with emergency disconnection of one of the grid's elements, while another one being under scheduled repair shall be taken into account.

In the process of implementation of the designed circuit diagram of the EPG basic grid, there is allowed a temporary non-complete backing-up of individual assemblies, provided a capacity deficit caused due to repair of any damaged element does not exceed (taking account of reserve sources use) 25% of the assembly's maximum load.

When selecting the connection circuit design for electric power plants and step-down substations to the basic electric grid, responsibilities for supplying the customers and a necessity to maintain transit power shall be taken into account.

Connection circuit designs for large plants shall provide a possibility to yield a full capacity of the electric power plant to the basic grid (except for the own-needs load and a capacity provided to the distribution grid) at all the stages of capacity commissioning at any time of a day and a year, with all outgoing overhead lines being operating. During maximum load hours of the EPG, output of full capacity of the electric power plant shall be provided, as a rule, even with one of the outgoing overhead lines being disconnected; in separate cases the electric power plant capacity restriction is allowed within the limits do not exceeding the capacity of the largest unit, with the specified repair schedule.

As a rule, not more than two overhead lines of the same voltage shall be constructed between two nodes of the basic electric grid. If it is necessary to strengthen the grid additionally an expediency to construct overhead lines along other routes or transition to higher voltage shall be considered.

When designing the development of electric power systems and basic electric grids, three-phase and one-phase short-circuit currents shall be calculated to reveal the requirements imposed on commutation equipment and other equipment of switchgears under designing, as well to check the correspondence of the existing switchgears' equipment to designed values of short-circuit currents. Short-circuit currents (and if necessary, voltage restoration rates) are calculated when developing the electric power system development scheme; the calculations are to be made for 10 years, and when developing the EPG development schemes for the nodal points of the basic grid short-circuit currents shall be estimated for a term of 15 years.

Short-circuit current levels (periodic component) on busbars of electric power plants and substations shall not exceed: 31.5 kV at voltages of 100 to 150 kV; and 40 kV at voltages of 220 to 330kV.These levels are only allowed to be exceeded in individual cases with special justification provided.

In the projects of the EPG and electric systems development, electric connections' circuit diagrams and objects' basic parameters, together with locations and objects' capacities, shall be selected preliminarily, with conditions of their operation within the EPG and correspondence to the requirements of technological designing of HPPs, TEPPs, and substations being taken into account.

Based on designs of development schemes for the EPG and the sites to which electric power plants are to be connected, there are preliminarily determined: voltages at which the electric power plant power is to be output to the basic electric grid (as a rule, not more that two voltages are accepted); number and directions of overhead lines outgoing from switchgears of each of step-up voltages; recommended allocation of units between voltages; necessity of connections between two step-up voltage switchgears and power transfer through these connections (or connection autotransformers' power); requirements to principal circuits, and in some cases to electric equipment of electric power plants, which are related to provision of parallel operation stability and PA applications (switchgear bus sectionalization, emergency shedding value); and short-circuit current values. In addition, the data of EPG development design determines power value, which is ultimately permissible in accordance with emergency back-up conditions (reserves of power and basic electric connections' transmission capacity) and which may be lost if any breaker, including bus connecting or sectional one, of the electric power plant is damaged.

### 3.2.6. Substations (SS) Design

In order to implement design of step-down SS when designing EPG and electric power systems development (as well as when designing external electric power supply schemes for large consumers), the followings are determined preliminarily: SS location region, switchgear voltages, recommended circuit diagrams of switchgear electric connections (in the designs of electric grid development – switchgears of 110 kV and higher) and requirements to the grid sectionalization; number, capacity and rated voltages of transformers (autotransformers); SS electric loads for the designed periods; 110 kV-and-higher overhead lines number and voltages, and voltage adjustment limits on SS busbars, types and capacities of compensating devices, grounding regime for transformer's neutral conductors, as well as requirements to system's automatic equipment.

Technological design specifications for SS with highest voltage of 35 to 750 kV stipulate obligatory application of typical switchgears circuits for all voltages. Application of non-typical circuits designs is only allowed with availability of feasibility study (in particular, for substations under reconstruction).

These specifications stipulate installation, as a rule, of two transformers at SS; installation of more than two transformers is allowed if a feasibility study is available, as well as in the cases if there are required two mean voltages at SS. It is allowed to install one transformer for the first period of operation provided consumers' supply is back-up on medium- and low-voltage grids.

Transformers' power shall be sufficient to supply consumers, taking account permissible overloading and medium- and low-voltage grids' reserves, in case of disconnection of the most powerful one of them (for a period of repair or replacement of out-of-order transformer). The power of each of transformers for the two-transformers SS, if there is no back-up on medium- and low-voltage grids, is selected taking account of transformer's loading being not more than 70% of the SS maximum load for the designed period.

As a rule, three-phase transformers are to be installed at SS with the highest voltage up to 500 kV. If three-phase transformers of the required power are not available, then paired three-phase or one-phase ones may be installed. When installing one group of paired transformers a reserve phase with a possibility to connect by means of jumpers (with voltage disconnected) shall be provided. When installing two groups the provision of a reserve phase shall be determined by technical-and-economic calculations taking medium-voltage grid reserve into account.

### 3.2.7. Electric Power Plant Circuit Design

The technological designing specifications for TEPP provide instructions for selection of types of step-up transformers and transformers (autotransformers) of connections between higher voltage switchgears and for installation of reserved transformer power.

In a number of cases the selection of an option for two higher voltages connections – using of two three-winding transformers or connection autotransformers according to blocking oscillator-transformer circuit or as separate transformers, their connection through one or two circuit breakers, installation of one three-winding transformer and even refusal of connection transformers – are to be justified by technical-and-economic calculations when designing TEPP.

A total power of transformers connecting the higher voltage switchgear in TEPP (KEPP and heat-and-power plants) with switchgear of generator voltage shall provide output of all the true and reactive power of the electric power plant to an electric power system except for the own-needs load and generator-voltage grid load during a period of minimum local load. Output of true power produced by an electric power plant in non-working days to the grid shall be provided as well.

The mentioned transformers' power shall be sufficient to supply consumers fed by generating voltage during a period of maximum load when the most powerful generator connected to this switchgear is disconnected. When determining required power of transformers, consumers supply conditions in summer time shall be taken into account, if heat generating units are to be stopped due to heat load reduction.

A damage or failure of any breaker shall not, as a rule, result in disconnection of more than one circuit (two overhead lines) of transmit with voltage of 110kV and higher, if the transit line comprises two parallel circuit. Repairing of any of 110kV-and-higher voltage breakers shall be possible without disconnection of the connection.

As a rule, an overhead line disconnection shall be performed with not more than two breakers, and disconnection of step-up transformers, connection transformers and own-needs transformers with not more than three breakers of a switchgear of each step-up voltage.

When TEPP generators are connected into units with three-winding transformers (autotransformers), then a breaker is installed between a generator and a transformer.

For HPP it is stipulated that it is possible to apply the following types of electric power units: a single generator transformer unit; an enlarged unit comprising several hydrogenerators connected to one step-up transformer or a group of single-phase transformers through breakers or without them; an integrated unit comprising several single or enlarged units connected each other without breakers on high voltage side of transformers.

# 4. PROVISION FOR EPG RELIABILITY

## 4.1 Governing Instructions on Energy System Stability

### 4.1.1. General provisions

The governing instructions establish requirements which an energy system shall satisfy with respect to stability.

The requirements to energy system stability may be altered compared to these given in this document, taking specific conditions into account, if a feasibility study is available.

**Table 1.**

| **Disturbance** | **Group of rated disturbance in grids with rated voltage, kV** | |
|---|---|---|
| | 110-220 | 330-500 |
| Failure of any grid element without short-circuit | 1 | 1 |
| **Short-circuit in electric transmission line** | | |

| | | |
|---|---|---|
| One phase with successful reclosure (for 330kV and high-one phase reclosure, for 110-220kV-three phase reclosure) | I | I |
| One phase with unsuccessful reclosure (for 330kV and higher-one phase, for 110-220kV-three phase) * | I | I |
| One-phase with failure of one breaker and UROV action | II | III |
| Multiphase with failure of one breaker (for 330-750kV grid - one of breaker's phase) | III | III |

*) when automatic reclosure is forbidden in case of arc non-extinction, unsuccessful reclosure may be not considered.

A designed duration of short-circuit is assumed to be a higher limit of actual values, which correspond to basic protection operation. When Designing measures providing short-circuit duration, which does not exceed the values indicated in Table 1a, shall be stipulated.

### 4.1.2. Standard Disturbances

Disturbances, which are accounted in the energy system stability requirements, are divided into three groups: I, II and III. The groups contain the following disturbances:

a) a grid element disconnection without and with short-circuit (distribution according to the groups in shown in Table 1);
b) occurrence of emergency power imbalance due to any cause-disconnection of generator or generators unit with a common breaker on high voltage side, large substation or large consumer, ÏÏÃ (distribution according to the groups is shown in Table 2).

In addition, the following disturbances are included into the group II:

c) simultaneous disconnection of two circuits located in a common corridor for more than a half of the shorter line length with the group I disturbance in accordance with Table 1;
d) disturbance of the groups I and II with disconnection of a grid element or a generator, which result in disconnection of another grid element or another generator connected to the same switchgear due to repairing of one of the breakers:

If during short-term interruption of supply to a large consumer, which is caused by short-circuit, reclosure pause and so on, engine run-out is possible with subsequent group restarting, then it is necessary to take account of reactive load surge as one of the group I disturbances.

**Table 1a.**

| | |
|---|---|
| Rated Voltage, kV | 330 |
| Short-circuit disconnection time, sec | 0.14 |

**Table 2.**

| Emergency Power Imbalance Value | Rated Disturbance Group |
|---|---|
| Not more than power of generator or generators unit except for the most powerful, which are present in a small quantity in the EPG | I |
| Not less than the imbalance for the group I, but not more than:<br>maximum power of generator or generators unit of the EPG; | II |
| Not less than the imbalance for the group I, but not more than:<br>power connected to one section (system) of busbars of one voltage switchgear of the electric power plant<br>50% of the electric power plant capacity | III * |

* - emergency  imbalance of the Group III are related to the case, when a stability of parallel operation through the adjacent EPG connections.

### 4.1.3. Section True Power Static Stability Factor

A Static stability factor according to true power in a section (Kp) is calculated by the formula:

$$Kp = \frac{\qquad\qquad}{P} \qquad (2)$$

where:

Pnp is true power transmitted through the section in question (transfer in a section) in a regime which is limiting with respect to a static stability;

P is transfer in this section in the regime in question;

ÄP is an amplitude of true powers non-regular oscillations in this section in the regime in question (it is assumed that the transfer P is varying within P+ÄP range due to non-regular oscillations)

Determination of the transfer limiting with respect to a static stability in the section is performed by means of hardening of the regime (increase of transfer). Regime hardening trajectories, which are sequences of established regime, which allow to reach a static stability domain boundary by changing one parameter or a group of parameters, are considered.

It is necessary to consider increase of transfer in a section for a number of hardening trajectories, which are characteristic for the EPG and are differing in redistribution of capacity among nodes located on each side of the section in question. Pnp values are determined along to the trajectory, to which the minimum ultimate capacity corresponds.

It is allowed to consider only regime hardening methods, which are balanced in capacity, i.e., such methods where frequency remains practically unchangeable. If, for specific conditions the transfer increase may be caused or accompanied by a significant change in frequency then such methods for regime hardening shall be considered as well.

The transfer limiting with respect to static stability are determined taking account of rotor-current overload of generator, which is permissible for 20 minutes.

A higher overload is allowed to take into account (in all regimes, except for post-emergency one), if during a permissible time such an over load is automatically liquidated without reducing a stability reserve in the section (automatic starting of hydrogenerators, their transfer from a compensatory regime to an active one, etc.).

True power non-regular oscillation amplitude value (ÄP) in the section in question, which is entered into (2), is determined for each section of the EPG according to measurement data.

If such data is absent, the computed amplitude of non-regular oscillations of true power, MW, may be found using the following expression:

$$\frac{Ph1 - Ph2}{Ph1 + Ph2} \qquad (3)$$

where: Ph1, Ph2 are total powers of load on each of the sides of the section in question (MW), and the coefficient to (MW) is assumed to be equal to: 1.5 for manual adjustment and 0.75 for automatic adjustment and restriction of power transfer.

During operation it is necessary, as a rule, to use true power transfer values to control the rated reserves of static stability.

When necessary, maximum permissible and emergency permissible transfers are given as functions of transfers in other section and voltage at nodal points of the energy system. Such transfer and voltage are to be included into controllable parameters.

Depending on specific conditions other parameters of the energy system regime, in particular the values of angles between the voltage vectors at the ends of the electric transmission, may be used as controllable parameters. Permissible values of the controllable parameters, which provide a rated reserve factor according to true power, are determined based on computations.

### 4.1.4. Load-Node-Voltage Safety Factor

Voltage Safety factor values (Ku) are related to load nodes and are computed by the formula:

$$Ku = \frac{U - U_{kp}}{U} \qquad (4)$$

where: U is a voltage at the node in regime considered;
$U_{kp}$ is a critical voltage at the same node, which corresponds
to a limit below which the stability of engine is violated.

The critical voltage at 110 kV-and-higher voltage load node, as a rule, shall be accepted not less than 0.7 $U_{norm}$ and 0.75 $U_{norm}$, where $U_{norm}$ is the voltage at the load node considered in a normal regime.

To control the rated reserves cording to voltage at load node during operation voltage at any nodes of the EPG may be used. Permissible values of voltage at controllable nodes are determined by the EPG regimes' calculation.

### 4.1.5. Requirements with Respect to Energy System Stability

Minimum static stability factor according to true power in sections and load-node voltage are rated according to the EPG stability conditions.

In addition, the groups of disturbances which shall provide both dynamic stability and rated coefficients, static stability reserves in post-emergency regimes, are found.

There requirements may be performed by:

- strengthening of the electric power grid;
- reduction of short-circuit disconnection, improvement and optimization of reclosure device adjustment (e.g., using the cintrol of arc extinction during reclosure pause, selection of order for supplying electric power lines with voltage, reclosure pause duration changing, etc.).
- application of systems and devices for automatic prevention of stability violations; and

- changing of the EPG operation regime.

The reserve factors are normalized according to an a periodic static stability, while absence of self-oscillation shall be provided in the permissible domain of regimes. If a self- oscillation occurred, then measures to eliminate it shall be undertaken, and the section where oscillations are observed, shall be urgently shaded additionally, till these oscillations vanish.

Besides that, the absence of thermal overload of the equipment shall be checked for permissible transfers, taking account of the regime existence duration, as well as other existing restriction, which are not related to the energy system stability.
The stability index values shall not be less than those shown in Table 3.

**Table 3.**

| Transfer in section | Minimum reserve factors according to true power, $K_p$ | Minimum reserve factors according to voltage, $K_u$ | Groups of disturbances, which shall provide stability in a section | |
|---|---|---|---|---|
| | | | for normal circuit design | for repair circuit design |
| Normal | 0.20 | 0.15 | I, II, III | I, II |
| Hardened | 0.20 | 0.15 | I, II | I |
| Forced | 0.08 | 0.10 | ----- | ----- |

When designing the EPG according to a normal circuit design and normal transfer, the stability at the group I disturbances in 500kV and lower grid shall be provided without application of PA.

When operating the EPG according to a normal circuit design and normal transfer in the case of group I disturbances the stability shall be provided without application of PA, except for those cases, when:

- requirement implementation results in a necessary to restrict consumers or lose hydroresources;
- due to disturbance the static stability limit in the section is reduced by more than 25%.

In the start-up schemes of the objects it is allowed to apply PA in order to prevent stability violation with the group 1 disturbance.

A post-emergency regime established after rated disturbances should meet the following conditions:

- the power reserve factor shall not be less than 0.08; and
- voltage reserve factor shall not be less than 0.1.

The post-emergency regime duration is determined by time required by a dispatcher to restore normal regime conditions, which is, as a rule, not more than 15 to 20 minutes.

Occurrence of additional disturbances (i.e., superimposition of accident on accident) during this time is considered.

The stability in the conditions of disturbance resulting in weakening of the section may be not preserved (except for conditions specified in the following cases):

- a limit of static a periodic stability in the section considered is reduced by more than 70%; and
- a limit of static a periodic stability according to links remained in the section does not exceed triple amplitude of non-regular oscillations of power in that section.

In this case division on links remained in operation shall not result cascade development of the accident, with PA operating properly. In the mentioned cases automatic division of the EPG on this section shall be provided before an asynchronous regime or its initial stage occurred.

During operation any deviation from the requirements related to a normal transfer (the first line in Table 3) means a transition to forced transfer and shall be permitted by a superior operative body, which is responsible for or controls this section circuits. A transition to a forced transfer in the section during the time for passing the maximum load, but not more than 40 minutes, or for a time required to introduce restrictions for consumers, and in the post-emergency regime included the time required to mobilize reserve (including cold one), may be carried out urgently with the permission of the on-duty dispatcher of the mentioned superior operative body.

Operation with forced transfer is not permitted, if the stability violations at the groups I or II disturbances and proper operation of PA may result in disconnection of automatic frequency adjustment and SAON from consumers, with a total power exceeding the consumers' restriction value by a factor of more than 10, which will be required to provide the rated indices of normal transfer.

An automatic cessation of asynchronous regimes in the EPG shall be provided by means, as a rule, of the grid division. Resynchronization both with automatic equipment application and arbitrary shall be back-up by a division.

Permissible duration of asynchronous regime and its cessation methods are to be established for each section, taking account of the necessity to prevent damages to the EPG equipment, additional synchronizing violation and interruption of consumers' electric power supply. A special attention shall be paid to the stability of electric power plants and large load nodes, where a center of oscillations may occur.

#### 4.1.6. Verification of Energy System Stability Design Requirements

Computation of the EPG stability and design verification of measures aimed at its provision is a necessary part of on designing and operation of the EPG.

The stability is to be computed when:
Selecting a basic circuit design for the EPG and revising the basic equipment location:

- Selecting the EPG working regimes;
- Selecting measure to increase the NPG stability, including PA facilities;
- Determining parameters for adjustment of PA systems designed to increase the EPG stability; and
- Checking implementation of rated stability indices and other requirements.

In addition the stability computations shall be done when developing and revising the requirements to a basic equipment of the energy system, relay protection, automatic equipment and regulation systems with respect to the NPG stability conditions.

The issues related to verification of implementation of the normative requirements of Section 3, which includes computation of steady-state normal and post-emergency regimes, estimation of their static stability, determination of regimes limiting with respect to stability, calculation of static stability reserve coefficients, determination of stability at rated disturbances (computation of dynamic stability), are discussed below.

***Computation of Steady-State Regimes***

When verifying the NPG stability the regimes corresponding to characteristic points in the schedules of daily and seasonal generation and consumption at possible normal and repair schemes shall be considered. These regimes shall be considered as existing for a long time.

Generators in the steady-state regime computation shall be assumed as unchangeable voltage source (at the designed points of voltage maintenance) with given true powers. It is recommended to define minimum and maximum values of available capacity taking account of voltage and true power values in a given regime. It is possible to define a fixed reactive power (instead of voltage).

As a rule, the load nodes shall be presented by true and reactive power values independent on voltage.

The post-emergency regime parameters shall be obtained taking account of all the changes caused by a transition process, including PA actions, as well as overloading limiters of the generator’s excitation windings and the synchronous compensators. Frequency change shall be taken into account if a significant power imbalance is present.

When computing the post-emergency regime the load nodes shall be presented by static voltage characteristics taking account of ARNT actions, and the static frequency characteristics of generators and loads shall be taken into account when the frequency is changing.

### *Computation of Static Stability of the EPG*

In the cases when the aperiodic static stability domain is close to the regime existence domain, it is allowed to be restricted by checking of the regime existence only.

When computing the aperiodic static stability and if the condition $U > U_{kp}$ is violated in any load node, then the corresponding regime shall be considered aperiodically unstable.

Oscillating stability shall be computed:

In the conditions of operation if there are data on possibility of occurrence of undamped or slightly damped oscillations, in order to determine permissible regime domain and efficient measures for prevention of oscillating violation of stability;

When designing, if difficulties in providing the oscillating stability may be expected, in particular, if new equipment such as generators, excitation systems and ARV will be used at the electric power plant.

When verifying the aperiodic stability, it is allowed presenting the generators as unchangeable voltage sources (at the designed points of voltage maintenance, depending on ARV type) with given true powers, and the loads – by static characteristics without taking transformers' voltage regulation into account.

### *Determination of Regimes Limiting with Respect to Stability.*

In order to determine the stability reserve factor with respect to true power in the section the hardening of the regime is carried out by means of increasing of power transfer in the section till a regime limiting with respect to stability will be reached.

The hardened regime trajectory shall change greatly a regime of the section considered. Computation of hardened regimes is accompanied by checking their static aperiodic stability.

In order to increase transfers in the section considered when computing, it is recommended to load generators on the one side of the section and to shed them on the other one. Reaching the limits according to maximum or minimum capacity of generators it is recommended to increase transfers by corresponding decrease or increase of the load's true and reactive power. If the load is decrease down to a possible minimum in actual conditions, then for further increasing of transfers it is necessary to overload generators removing the corresponding limitations (according to generator stator current, to transformer current, to power of units and so on, except for limitations according to rotor current).

If the considered section links two parts of EPG, with the smaller one being deficit, then the main method for regime hardening in this section shall be increasing of the EPG deficit part load.

If other factors causing transfer increase are characteristic for a specific situation, then to harden the regime such methods shall be considered as well.

When hardening the regime, it is allowed to represent generators as it was done when computing a steady-state regime, and the restrictions in generators' reactive power shall be as it was indicated above.

Generators' true power changes under the influence of secondary regulation are to be taken into account, if necessary. In this case all the automatic control devices preventing reaching at limiting transfer in this section (automatic restriction of transfer, Fault Protection equipment) shall be considered being disconnected.

Large load nodes located at the EPG points where significant voltage changes (more than 10 to 15%) are possible when hardening the regime, shall be represented by static characteristics taking ARNT into account. For other loads it is allowed to assume $P_n$= const, and $Q_n$ = const.

In the case of hardening a regime by means of load increase, it is recommended to assume the increase of reactive load, if actual data is absent, to be proportional to the increase of true load with a proportionality factor being equal to 0.5 to 0.7 $M_{var}$ /MW.

When considering hardening trajectories with significant frequency changes, there shall be additional static characteristics of power vs frequency for generators and loads.

Determination of a critical voltage in a load node has the following capabilities:

If there are synchronous motors operating with disconnected ARV at the load node, then the critical voltage shall be assumed to be equal to 0.85 $U_{nom}$; to revise them the computations accounting the parameters of motors and their excitation systems are needed.

If there are specific electrical receivers (e.g., direct current electric drives) at the load node, then $U_{cr}$ values shall be specified taking account of corresponding departmental regulations.

If there are long or highly loaded lines of a distribution grid (which are not included into the designed circuit diagram of the energy system) at the load node, then the critical voltage shall be revised by calculations according to a special designed scheme. This scheme shall take into account: a distribution grid fed from the considered node; adjustment of step-down transformers' voltages; static voltage characteristics of all the basic groups of electric set-ups and their critical voltage values. The EPG part, which is external with respect to the node, is not accounted and the node in question is assumed to be a balancing one (BN). In the first computation of voltage the BN is assumed to be equal to a normal voltage at this node. In the following computations the BN voltage is reduced from one calculation to another.

A critical voltage is assumed to be equal to a minimum voltage of the balancing node, at which a static aperiodic stability of the load node is maintained, but not less than $U_{cr}$ values mentioned above.

***Computation of Dynamic Stability***

It is recommended to apply design models, which account electromagnetic transition processes in the excitation winding and damping circuits and transition processes in the excitation system, including ARV, in the computations of dynamic stability for generators close to the short-circuit point. It is allowed to substitute other generators with unchangeable-in-value emf behind the transition resistance.

When computing short-term transition processes, it is allowable, as a rule, to assume turbine capacity being constant.

In computation of dynamic stability for large load nodes (especially for those located near generators simulated in details and in the sections where the energy system stability may be distorted) the equations of induction motors, as well as those of synchronous motors, if the power consumed by the latter is significant, shall be applied.

For other load nodes it is allowable, as a rule, to use static characteristics, and in the nodes where voltage drop in the transition regime (after disconnection of short-circuit) does not exceed 5 to 10% it is allowable to represent a load by a constant resistance, and for the locations far away from short-circuit by a constant power or by taking it into account in the generating nodes' balance.

Self-disconnections of electric receivers at deep voltage drop shall be taken into account too. The verification of stability requirements implementation at rated disturbances shall be carried out taking account of PA action designed for automatic prevention of stability violations (APSV), i. e., include the verification of APSV efficiency.

The EPG designed models are revised taking account of the operation experience with a help of experiments in the nature.

## 4.2 Relay Protection Systems

All the elements of the basic EPG of Moldova (lines, transformers, autotransformers, busbars) shall be equipped with high-speed relay protection, which activation time does not exceed 20 to 25 ms, and a total time of short-circuit disconnection with time of disconnection itself (50 ms) is about 80 ms.

Relay protection devices must disconnect damage using all necessary means of back-up since the energy system without short-circuit being disconnected is impossible.

In order to liquidate short-circuit in the case the basic relay protection or overhead line (transformer) breaker failed various back-up methods and facilities are envisioned**: long-distance ones** at neighboring substations and **close ones** at own substation.

The long-distance facilities include: back-up multi-stage relay protections from inter-phase short-circuits (remote) and from short-circuits to ground (directed current of zero succession); remote disconnection devices (transmission of disconnection command for the breaker installed at the far end of the line) when the first remote relay protection is activated.

High-frequency channels with transmission of signals via wires and earth-wires of the overhead line being protected, as well as microwave channels, are used for relay protection purposes. Abroad the microwave link lines with signal transmission both in telephone channel band and in the band up to 47kHz with transmission rate up to 40kbod are used for the purposes of relay protection and automatic equipment.

In the course of the energy system development a long-distance back-up by means of relay protection of adjacent elements becomes more difficult or non-effective because of impossibility to provide the required sensitivity, the required speed of short-circuit disconnection as well non-selective disconnection of large number of connections.

Close local back-up facilities include: back-up device for breaker failure (BDBF); doubling, i.e., application of two or sometimes three basic relay protection on the overhead line (usually of various types, e.g., differential-phase and distance with transmission command for remote disconnection) connected to various current and voltage transformers, various automatic breakers (fuses) of direct operative current and affecting different coils of breaker's disconnection; special current or remote bus connecting (or sectional) breakers, which divide the systems (or section) of busbars if there is non-disconnect short-circuit on the elements outgoing from buses, and which results in increase of sensitivity and selectivity of back-up relay protection performing long-distance back-up.

In the future microprocessor units, containing technical diagnostic facilities together with relay protection, as well as emergency information recording devices, will find wider applications. Accumulation of the data base for emergency information will allow to improve both operative analysis of emergencies occurred and retrospective analysis allowing to evaluate proper operation of antifailure measures and to reveal automatic device faults.

The main advantages of microprocessor devices are as follows:

- high reliability of device functioning due to permanently operating self-diagnostics;
- simplicity of technical and operative maintenance with lesser expenses for training of personnel and operation;
- possibility to obtain any form of characteristics;
- possibility to obtain devices reacting to emergency current and voltage components;

- automatic adaptation  to changing of the grid circuit design and regime;
- simultaneous  adjustment of several settings in one relay with putting any of them into operation from any operative control level;
- recording of analog and discrete information in emergency regimes and transmission of this information to any level of dispatching control;
- monitoring of normal regime parameters from any level of dispatching control;
- integration with the systems of control and monitoring of object;
- possibility to be included into expert system of the energy systemor object monitoring to help on-duty personnel and services of the relay protection  of Moldova.

## 4.3 Automatic Reclosure

All overhead lines and many buses of the EPG basic grids substations are equipment with automatic reclosure devices.

Automatic reclosure devices assist in preventing development of emergency situations and in the restoration of the grid’s normal circuit design by means of restoring the relay protection on lines or buses after unstable damages, false or extra activation.

## 4.4 Fault Protection Equipment

### 4.4.1. General provisions

In order to prevent the occurrence and development of emegency distortions in the EPG and to speed up restoration of the normal regime, automatic fault protection equipment shall be used. Its application prevents occurrence of system incidents which are accompanied by interruption of electric power supply of consumers over a large area.

A set of automatic fault protection equipment comprises several subsystems fulfilling the following functions:

- automatic prevention of stability violations (APSV);
- automatic elimination (termination) of an asynchronous regime;
- automatic restriction of frequency reduction;
- automatic restriction of voltage drop;
- automatic restriction of frequency and voltage increase; and
- automatic shedding of equipment.

The  automatic fault protection equipment shall implement the following function in accordance with a set of monitored indices:

- to evaluate the EPG conditions;
- to reveal presence of an emergency and to assess its severeness; and
- to determine necessity and required intensity of control action.

### 4.4.2. Control Effects of Fault Protection Equipment

Automatic fault protection equipment shall implement the following basic control actions:

- turbine shedding;
- generator disconnection;
- load disconnection;
- programmed focusing of generators' excitation;
- control of longitudinal and transversal compensation set-ups;
- compensation focusing, starting by-passing reactors; shutting down of by-passing reactors;
- separation of the energy system into non-synchronously operating sections;
- capacity reserve realization;
- disconnection of individual electric power lines and link transformers, sectional and interbus breakers, which does not result in the energy system separation; and
- connection of loads disconnected earlier, electric power lines, transformers and breakers disconnected in due procedure.

Other types of control actions are under development, are under introduction into practice or have limited application other than those mentioned above:

- electric breaking of generators;
- loading of steam turbines by affecting a regulation system or by disconnection of high pressure take off, and thermal take off;
- loading and unloading of hydroturbines;
- control of transmission power and direct current load, etc.

It is recommended to apply control actions discretely, i.e., control action of specific intensity, prepared beforehand by a corresponding signal.

Taking account of possible damage, it is expedient to use a specific priority of control actions, which depends on the action purpose and type of automatic fault protection equipment. Control actions with lesser priority shall be used when higher priority control actions capabilities are exhausted, or they shall be used as back-up actions, or when the system is not ready to use higher priority control actions. When selecting a control action, it is necessary to take account of electric technical and energy equipment conditions.

***Turbine off-load***

A steam turbine off-load is implemented through a regulation system using two inputs: high-speed input, electrohydraulic converter; and low-speed input, turbine control mechanism.

Two types of turbine off-loading are used: short-term and long-term.

<u>Short-term (pulsed) off-loading of a steam turbine (SLT)</u> is a rapid reduction of turbine capacity due to closing of regulating valves for a few seconds. It is used during the automatic prevention of stability violations to reduce excessive kinetic energy of generating units' rotors at the initial stage of transition process caused by emergency disturbance. Action intensity is characterized by depth and rate of off-loading.

The SLT is realized by feeding a square pulse to the electrohydraulic converter with further exponential decaying at the rate approximately corresponding to a damping of electromechanical oscillations in the energy system.

The amplitude and duration of the pulse's square part is selected taking account of experimental dependence of off-loading depth on pulse parameters (pulse diagrams). Usual amplitude change range is 1 to 4 arbitrary units, duration is 0.1 to 0.3 sec.

The SLT step of the electric power plant may differ in amplitude or duration of the pulse's square part, as well as in number of generating units to be off-loaded. When selecting units for emergency off-loading, the expected frequency and discreteness of SLT shall be taken into account due to restricted resources of each generating unit.

<u>Long-term off-loading of a steam turbine (LLT) or capacity restriction</u> is a long-term solution due to the closing of the turbine's regulating valves and corresponding reduction of the boiler unit efficiency.  It is characterized by off-loading depth; and may be implemented through the electrohydraulic converter and/or control mechanism of the turbine and shall be accompanied by feeding of corresponding control actions to the boiler regime's regulating system.

Use of the LLT provides:

- the prevention of stability violation;
- the elimination of asynchronous regime; and
- the restriction of equipment overloading.

The restriction steps may differ in restriction signal value or number of units to be off-loaded. The LLT is realized by generated units and power plants devices of capacity restriction. Units automatically go to restriction depth based on the plant's devices.  Power plant personnel are allowed to use capacity restriction devices with and without a regulating circuit closed according to unit's power.

The first type of devices are used first because of higher accuracy of restriction. The power plants' devices allocates a given load according to units (energy units) taking account of their adjustment range, as well as allocation of units in the case of the system separation. If a total adjustment range of the electric power plant is not enough, then an additional generator disconnection is carried out.

Generator disconnection is used for:

- prevention of stability violations;
- elimination of asynchronous regime; and
- restriction of frequency increase and equipment overloading.

The generators' disconnection is carried out by generators' or generator-transformer units' breaker disconnection. These breakers shall be selected taking account of:

- provision of required high-speed action and disconnection reliability;
- number of generators to be disconnected by means of opening the corresponding breakers;
- a circuit diagram of the electric power plant high voltage.

If the specifications of technological automatic equipment and the regulating system of unit's rotation rate do not provide a reliable operation of the unit at idle run or with plants internal power needs at TEPP, then the generators disconnection device will close the stop valves with further disconnection of the breaker, provided high-speed action is sufficient to implement automatic fault protection equipment functions.

When selecting control action type, it shall be taken into account that the generators disconnection:

- is preferable at HPP than at TEPP;
- is expedient at TEPP only after exhaustion of capacity restriction possibilities; and,

When selecting the generators to be disconnected, the possibility of keeping generating units operating to satisfy their own internal plant load will be considered.

Load disconnection is used for:

- restriction of frequency and voltage reduction;
- prevention of stability violation;
- elimination of asynchronous regime;

- restriction of equipment overloading.

Since the load disconnection is directly related to the non-supply of electric power to consumers, it is recommended to use automatic reclosure after load disconnection.

# 5. AUTOMATIC SYSTEM OF DISPATCH MANAGEMENT (ASDM)

An automatic system of dispatching management, based on contemporary computing facilities, and acquisition and mapping of information shall provide an effective support to the central dispatching control personnel at all the stages of regime planning and operative and automatic control.

# 6. DISPATCH COMMUNICATIONS SYSTEMS

## 6.1 Dispatch Telephone Communications (DTC)

The DTC shall be organized on two or more mutually back-up channels; one of them shall be non-commutating. Communication channels shall have a transmission band not less than 2kHz and shall be connected to dispatching switches on the both sides.

Calls on DTC channels shall be carried out by means of simple commutation manipulations without dialing.

## 6.2 Facsimile Communications

The Dispatch Center shall be provided with facsimile communication for transmission of printed and graphic documents.

## 6.3 Telecommunications Channels

Telecommunications channels may be duplex or simplex ones and shall provide operation at rates of 50 to 2400 baud.

# 7. LONG-TERM PLANNING

## 7.1 General Provisions

In developing long-term planning regimes, the EPG's central dispatching control fulfills the following functions:

➢ develops annual, quarterly and monthly balances of capacity for the EPG;

- develops annual and quarterly plans of electric power production and transfer;

- draft proposal for correction of these plans (agrees to the plans to the quarter months with operations department);
- determines technical and economic indices of HPPs and calculate hydroresource use efficiency;
- calculates and analyzes fuel resource provisions;
- participates in development of operative plans for various- fuel types and keeps track of actual energy regimes of the existing fuel market;
- forecasts electric power consumption and typical daily load schedules for a period of long-term planning;
- calculates energy regime and draft schedules of load recovery for characteristic days of the planned periods, which are necessary for developing of optimum long-term plans of electric power production and transfer;
- takes into account technical-and-economic indices and analyzes use of individual groups of TEPP equipment;
- develops measures for improving electric power production structure and reduction of conditional fuel specific consumption;
- analyzes flexible use of TEPP equipment when regulating the regime;
- determines permissible value of capacity stut-down for repair;
- prepares proposals on optimization of overhaul and medium repairs of electric power plants' basic equipment;
- agrees on annual maintenance plans;
- develops monthly plans for repairing of equipment;
- monitors electric power plants' equipment repair plans;
- establishes operation schemes of the basic electric power grid, included in the responsibility of the central dispatching control;
- develops the EPG regimes for characteristic period of the year (autumn-winter peak load, flooding, summer repair), as well as in the connection with introduction of new system's object into operation;
- determines planned loads flows and voltage regimes in the EPG basic grid;
- calculates optimum regimes of electric power grid for voltage and reactive power for characteristic days of the period (month, quarter);
- determines the order for use of voltage regulation facilities and provides the schedules of voltage at points controlled by the central dispatching control dispatcher;
- monitors the electric regime in general;

- develops provisions for elimination of “bottlenecks” of the basic electric power grid, which prevent reasonable use of capacities and optimum regimes observance;
- analyzes the structure and time history of losses in the electric power grid;
- determines measures for reduction of losses and improvement of voltage regimes;
- develops plans for intersystem and basic transit links repair, and supervises implementation of the plans;
- calculates stability, short-circuit flows, and asynchronous regime;
- determines ultimately permissible capacities transmitted through basic transmit links;
- assesses limitation parameters for various conditions of the EPG operation, as well as in the connection with the introduction of new system’s objects into operation;
- develops or agrees to requirements for equipping the basic electric grid of the EPG with relay protection, line and automatic fault protection equipment facilities;
- chooses setting of relay protection and automatic equipment of intersystem and transit links;
- agrees to settings and specifications of facilities included into the operative responsibility of the central dispatching control dispatcher;
- determines values and settings of automatic load shedding;
- instructs on application of special automatic equipment for load disconnection;
- prepares proposal on duration of capacity and electric power restrictions for consumers in case of long-lasting deficit of capacity and electric power (energy resources);
- upon approval of these restrictions, supervises their implementation; and
- compiles summary schedules of capacity and electric power restrictions and emergency disconnection of consumers from the supply center, according to RP data.

The Central Dispatching Control also fulfills other important functions related to long-term system planning and to optimization of the EPG development including:

1) provision of electric power import;
2) improvement of the system;
3) methods and operative dispatching control facilities; and
4) equipping the EPG with new system’s automatic equipment together with direct development of long-term regimes.

Fulfilling these functions the Central Dispatching Control prepares proposals on development of the EPG, and

- develops plans for introduction of new capacities of large grid’s objects;

- participates in development of requirements to new large energy equipment, dispatching and technological control facilities, facilities of automatic control of anomaly and emergency regimes;
- manages introduction of system's facilities and devices;
- participates in development of governing instructions for improvement of the electric power system operation's technical level;
- organizes research and development and adjustment works in increasing of reliability and economy of the EPG operation and electric power quality improvement;
- reviews and approves works on development and automatization of operative-dispatching control;
- performs general technical management of telemechanics and communication facilities operation by organizations and enterprises of the industry;
- coordinates construction and operation of communication trunks of the industry;
- operates technical facilities installed at the dispatching control room and the computer center of the Dispatch Center;
- develops provisions and instructions on operative dispatching control and operations;
- keeps current and generalized reporting of the EPG operation; and
- organizes the system's testing, which is related to determination of the energy system regime characteristics and introduction of regime control automatic facilities.

The Dispatch Center divisions perform methodological management, providing unified technical policy in operative control, improvement of methods and technical facilities of control, and organization of clear interaction between all the levels of management.

The Dispatch Center responsibilities for long-term planning of regimes are strictly restricted by the field of operative and regime operation:

- development of the energy system perspective development issues;
- planning of energy production and technical-and economic indices;
- compiling of technical-and-economic characteristics and determination of permissible regimes of equipment operation;
- management of equipping the energy system with relay protection, line and automatic fault protection equipment facilities, as well as location and adjustment of automatic restriction of frequency reduction, special automatic equipment for load disconnection, etc.;
- participation in development and introduction of measures for provision of electric power plants parallel operation stability, increase of basic load nodes and important consumers supply reliability, improvement of economic operation of electric power

plants and the energy system as a whole, increase of flexibility and control of electric power plants' basic equipment, reduction of electric power losses in the electric power grid, improvement of energy quality, automatization of dispatching control of the energy system and energy enterprises (energy objects);

- participation in inspection of electric power plants and grid readiness seasons;
- drafting of dispatching instructions, etc.;

The electric power plants' personnel receives from the Dispatch Center:

- data on optimum long-term plans of electric power production and energy resource use;
- instructions on restrictions subject to according in long-term planning;
- dispatching provisions and instructions, etc.

## 7.2 Forecasting

### 7.2.1. Load Forecasting

Initial forecasts of electric loads are used as input information for all the tasks of long-term planning. For each interval of the corresponding year (week, month) energy consumption and characteristic daily load schedules – for average working day, Saturday, Sunday and Monday – are forecasted.

The forecast is performed based on a statistical extrapolation of the past regime to the future. In this case it is expedient to take account of specific features of load changes for various groups of consumers (industrial, commercial, residential) and industry branches. The forecasted load adjusted to average monthly climatic conditions (air temperature and clouds are taken into account). In forming the input data, actual information on load and consumption schedules are adjusted to rated frequency.

Forecasting of electric power consumption for each month is performed on the historical basis of several years. Monthly consumption of electric power is determined as a sum of consumptions for individual days – for average working days, sum for Saturdays, Sundays, Mondays, holidays and day before holidays. For each forecast period, the total adjusted forecasted electric power (kwhs) is recalculated taking account the actual deviation of frequency value from the rated one, as well as temperature and illumination (clouds) from the mean multiyear values.

Peak demands shall be forecasted separately.

### 7.2.2. Forecast Of Available And Operating Power

To determinate the capacity and electric power balance for a coming period (year, quarter, month, day) the values of available and operating power of the electric power plants shall be forecasted.

In this case it is necessary to take account of disruptions and restrictions of the energy system capacities, and volumes of scheduled overhaul and current repairs (emergency reduction of capacity are determined by means of probabilistic calculations based on equipment availability indices).

The mentioned components of the electric power plant capacity shall be forecasted on the basic of both static methods (static extrapolation of the past to the future) and normative – information materials (e.g., determining periodicity and duration of scheduled repairs). The software for this forecasting is under development.

Depending on the length of long-term planning (month, quarter, year) individual components may be determined with a greater or lesser confidence. For example, lower efficiency generating units shut-down for “cold” reserve and conservation may be accounted with a sufficient confidence.

The capacities of units shut-down for overhaul and medium repairs are also practically definite values since these repairs are planned for a year, based on the normative periodicity and duration and taking the capacity balance into account.

The value of capacities of thermal electric power plants’ generating units, which are in urgent repair, are determined based on probabilistic characteristics observed over a number of years.

When determining the values of available and operating capacities, it is necessary to take in account the seasonal reduction of hydropower plants’ capacities. The lower capacity values are caused by reduction of head;

1) during spring flooding due to high tail race; and
2) during winter due to lowering of head-water because of water storage water-down.

Together with a forecast of available and operating capacities values necessary to meet costomer load, an amount of electric energy $W_{Ó}$, which could be produced by electric power plants, is to be determined for long-term planning. As the first approximation, a potential production of electric energy is evaluated by hour using the installed $P_{iy}$ capacity:

$$W \;=\; \underset{i = 1,\, n}{\quad} P_{iy}\, T_y$$

Where

$P_{iy}$ is an installed capacity of available equipment; and
$T_y$ is hours of energy using the installed capacity of the given type equipment.

### 7.2.3. Forecast of Equipment and Facilities Reliability Indices

Forecast of energy and electric technical equipment and facilities reliability indices, and those of control facilities in operational condition is usually determined by extrapolation or “direct propagation" of reliability indices' values obtained by statistical data to the coming period. If the coming period is not very long (not more than 2 to 3 years) than this method may be considered as acceptable. However, there are cases when it is impossible to obtain confident values of reliability indices for some part equipment based on retrospective data.

It is possible that operational experience of new types of equipment is insufficient to obtain confident data on their reliability, or is absent altogether. In some cases, new equipment reliability indices may be assessed estimated by considering the equipment as a system comprising elements for which reliability data may be obtained based on historical operation data of similar elements or based on test data. If this is also impossible, then the corresponding characteristics are to be forecasted by means of expert estimates.

Thus, the basis for determination of equipment reliability indices' values which are necessary for dispatching control at all the levels of territorial and temporal hierarchy, is, as a rule, statistical processing of historical information on the equipment vulnerability and restoration ability.

Vulnerability and restoration ability of equipment is determined by conditions of manufacturing and operation, as well as external (natural) conditions. Therefore, when gathering information, many events and conditions under which these events occurred are to be considered. The calendar time of equipment failure and shut-down of equipment for repairs, type of damage, character and duration of repair all characterize these events. These conditions are characterized by common elements (description, type and parameters, manufacturer, output date, etc.), operating conditions, causes of damages and putting to repair, etc.

### 7.2.4. Reserve

| Reserve | Reserve designation | Reserve value |
|---|---|---|
| National economy | Long-term planning compensation for potential increase of consumption and delay of introduction of new capacities | 2 – 3% $P_{max}$ |
| Repair:<br>overhaul and medium repair | Compensation for shut-down of equipment to repair during maximum annual load. | .05 – 1% $P_{distr}$ |
| | The same during summer decrease of load | up to 9 – 10% $P_{distr}$ |
| Current repair | The same during maximum load period | 3 – 4% $P_{distr}$ |
| | The same during remaining time | 4 – 5% $P_{distr}$ |
| | The same any time | |

| | | |
|---|---|---|
| Emergency repair | | 4 – 5% $P_{distr}$ |

# 8. SHORT-TERM PLANNING

## 8.1 General

Solving the problems of short-term planning of regimes, the EPG's Dispatch Center fulfills the following functions:

- forecasts daily load schedule for the coming period of short-term planning (from days to weeks);
- considers (permits, refuses) applications, determines work conditions for the most complicated permitted applications;
- instructs on changing the scheme and on regime preparation, correction of ultimately permissible capacity values, which are transmitted through controllable links, using and adjustment of protection and automatic facilities, changing of voltage schedules at control points, etc.;
- determines operating capacity of electric power plants;
- compiles capacity balances for morning and evening load maxima;
- checks, if necessary, capacity balance for the night minimum, and takes account of flexibility of electric power plants;
- determines restrictions on use of individual types of fuel, imposed on the EPG regimes, in accordance with fuel supply plans and actual situation with fuel reserves;
- determines duration of necessary load restrictions for consumers, if capacity and electric energy deficit is revealed;
- calculates optimization of the EPG short-term energy regimes;
- develops and approves daily schedules for the EPG operation – load schedules (consumed power), total capacity of the EPG electric power plants;
- delivers these schedules to the on-duty dispatchers; and,
- analyzes daily the EPG operation for the past day in order to find out causes for deviation from the given schedules and evaluate actions of the on-duty dispatchers carrying out the schedule and the correction of regime in case of deviations from the operation conditions, which were taken into account in planning.

## 8.2 Short-Term Forecast of the EPG and Energy Nodes' Loads

The forecast shall be done daily, usually for every hour of the next day (and before holidays and prior-holidays-days for several days). It is also possible to use weekly forecasts with their further correction every day.

When forecasting for a day or more (if the current day data are not known) the load of each hour is determined from the corresponding steady-state series of hour-by-hour loads of the several previous similar days, in accordance with minimum risk conditions.

When forecasting the load it is also expedient to use the load forecasts for regions, information on the planned operation regime of large consumers (for the EPG level) and information from the media.

Real and reactive load forecast at the electric grid nodes is necessary to provide information to electric and optimization calculation software.

The forecast methods may be based on two principally different approaches. The first method is similar to the one used for forecasting of the load schedule for the whole energy system and requires the same volume of information for each node and each type of load. The second method is based on using of statistical data about dependence of active loads of individual nodes on a total load of the energy system and dependence of reactive loads on active ones. Its application allows reducing the volume of needed initial information significantly.

It is important to adjust historical load data, especially reactive power, to rated voltage according to statistical characteristics, and if there are frequency deviations, to rated frequency. Depending on the structure of load forecasting software and the availability of each electric node's historical loads, the forecast may be done for every hour of a day or only for individual characteristic points of the daily schedule. In addition, the forecast may be calculated for only that part of the grid for which it is supposed to make electric power projections.

## 8.3 Short-Term (Daily and Weekly) Planning and Operative Planning

| Reserve | Reserve designation | Reserve value | Reserve Character | Reserve Mobility |
|---|---|---|---|---|
| Repair (for emergency repair) | Compensation for shut-down of equipment for emergency repairs within short-term planning cycle | 1-2% $P_{distr}$ | Hot (connected)<br><br>Non-connected | Minutes<br><br>Dozens of minutes-several hours |
| Load (regulating) | Compensation for load forecast uncertainty | 1-2% $P_{max}$ | Connected<br><br>Non-connected | Minutes<br><br>Dozens of minutes-several hours |
| Emergency: First category | Prevention of stability violation, automatic restoration of consumers' supply, which was disconnected by automatic fault protection equipment, frequency restoration | According to local conditions | Connected, and realized by automatic equipment actions | Parts of seconds-dozens of seconds |
| Second category | Elimination of current overload on electric power transmission line, restoration of normal reserves of stability, frequency restoration | According to local conditions | Connected or non-connected, starting up manually | Minutes-dozens of minutes |
| Third category | Restoration of normal regime with significant deficit of capacity | According to local conditions | Non-Connected | Hours |
| Load (regulating) | Automatic control Compensation for load forecast uncertainty and for unforeseen forced changes of electric power plant capacity | 1-2% $P_{max}$ | Connected, Starting up by automatic restriction of power drop | Seconds-dozens of seconds. |

# 9. NORMAL OPERATING REGIMES

## 9.1 General Provisions

Operative control in normal conditions performed by regulating the regime according to a given optimum daily schedule of operation with corrections (bringing to optimum additionally) of the regime when there are deviations of operating conditions from those accepted in the short-term planning. Solving problems occurring during normal operations, the dispatcher of the Dispatch Center and on-duty personnel of lower-level-control operation divisions carry out switching (stimulated by daily schedule or non-planned ones, which become necessary in the course of control) by means of changing the connection schemes of electric grids and energy objects, as well as the composition of connected equipment of electric power plants and electric grids (outages to repair or for reserve, start-up for operation after repair and reserve).

Acquisition, processing and documenting of operations information is performed at each level of the operative-dispatching control. The current regime is controlled by means of operative control facilities, including automatic control facilities, the conditions and adjustment of which are monitored by the on-duty personnel and are changed, if necessary.

## 9.2 Energy Regimes Control

**9.2.1. The dispatcher of the EPG Dispatch Center:**

- regulates the energy regime of the EPG;
- manages operatively the implementation of the optimum daily schedule of the EPG operation;
- supervises and provides implementation of the schedules of power transfers, total power and capacity hot reserve values, provided by the Dispatch Center;
- changes dispatching schedules in order to bring the energy regime to the optimum. Additionally, in case of deviation of the EPG operating conditions from the planned ones, adjusts capacity allocations, taking reliability and electric energy quality requirement into account;
- corrects the energy regime for changes in fuel supply;
- dispatches electric power plants and electric grids in accordance with the optimum schedule of the energy system operation;
- supervises implementation of capacity daily schedules by electric power plants;
- correct capacity allocation among electric power plants, by means of bringing the regime to optimum and in case of deviations of the energy system operating conditions from the planned ones;
- monitors the fuel stock for electric power plants, which have in sufficient fuel reserves, and undertakes measures to off-load those electric power plants in the accepted order, in case of unforeseen drastic decrease of fuel reserves;
- provides the required priority and timeliness of starting-up and stoppage of large units at electric power plants;

- supervises implementation of approved assignments on maximum capacity and technical minimum of capacity of units and electric power plants as a whole;

### 9.2.2. Senior Operative Personnel of Electric Power Plants

- regulates the electric power plant capacity in accordance with the given schedule and dispatcher's instruction;
- performs economical allocation of electric power and thermal power (on TEPP) between the units;
- manages switching in the basic scheme of the electric power plant, start-up and stoppage of units and auxiliary equipment impacting the capacity use, reliability and efficiency of electric power plant operation;
- provides reliable supply for own needs;
- maintains (on TEPP) thermal carriers parameters (pressure and temperature of steam and hot water supplied to consumers) at normal level;
- supervises fuel supply situation;
- manages the actions of subordinate operative personnel on maintaining of normal indications of TEPP technological regime and HPP water regime.

## 9.3 Control and Alternation of Circuit Configuration and Schedules of Electric Power Grid

### 9.3.1. The EPG Dispatch Center dispatcher:

- monitors the circuit configuration and regime of the EPG and changes them in accordance with the reliability conditions, if necessary;
- coordinates the actions of subordinate operative personnel for implementation of the given schedules of voltage at control points of the EPG basic grid and use of voltage regulating facilities, these providing optimization of the electric regime;
- prepares the EPG circuit design and regime to expected unfavorable meteorological events (storm, icing, hurricane) undertaking additional measures for reliability increase;
- manages the actions of RC dispatchers and operative personnel of energy objects on maintaining a reliable circuit design of the EPG basic grid, regulation of voltage and optimization of electric regime, as well as preparation to expected natural events;
- monitors and, if necessary, changes the circuit design and regime of the basic (supplying) grid of the energy system, providing reliable operation in parallel of electric power plants, by means of restriction, to permissible limits, power transfers through intersystem and internal transit links, as well as current loading of equipment;
- supervises preservation of reliable scheme of supply to load nodes and to important consumers;
- manager voltage regulation in the energy system, maintaining of voltage at control points in accordance with the given schedules and undertaking measures for maintaining of the optimum electric regime in the basic grid;

- supervises use of reactive power and loaded regulating devices for the supply grid's transformers; and,
- monitors the condition of the energy system basic equipment.

### 9.3.2. Senior Operative Personnel of Electric Power Plants

- provides regulation of voltage on the electric power plants' busbars, with optimum allocation of reactive power among generators.

### 9.3.3. Senior Operative Personnel of Electric Grids

- monitors the scheme and regime of the grid, which is in its responsibility, and, if necessary, changes the scheme and regime in accordance with the conditions of consumers' supply reliability and the grid's efficient operation;
- provides for maintaining of voltage levels in supply centers of the distribution network, which provide normal voltage at consumer's premises;
- regulates reactive power of CK;
- changes positions of loaded transformers' voltage regulating facilities; and,
- switches on and off condenser batteries in accordance with efficiency and electric energy quality requirements.

## 9.4 Equipment Shut-Downs and Start-ups

### 9.4.1. The Dispatch Center dispatchers and the senior operations personnel of electric power plants and electric grids:

- supervise shut-down of equipment from operation (or reserve) and its start-ups to operation (or reserve) in accordance with permitted applications;
- permit carrying of operations on equipment and facilities included in their operative control;
- prepare the circuit design regime and facilities of automatic equipment and relay protection to operations according to applications;
- manage the actions of subordinate operative personnel when operating on equipment and facilities included in their operative control;
- consider and resolve issues of non scheduled operations on equipment and facilities included in their operative control (if operation duration falls into one shift).

## 9.5 Monitoring Of Operative Control, Relay Protection, Line And Automatic Fault Protection Equipment Facilities, Their Decommissioning From, And Commissioning To, Operation

**9.5.1. The Dispatch Center dispatchers and senior operative personnel of electric power plants and electric grid:**

- supervise the condition of facilities and system of relay protection and automatic equipment included their operative control, maintaining and correspondence of relay protection and automatic equipment adjustment to the scheme and regime of the grid;
- monitor the conditions of dispatching and technological control and computing facilities;
- undertake measures to eliminate occurred faults;
- decommission relay protection and automatic equipment facilities from operation and commission them to operation in accordance with instructions;
- issue permission to service personnel for decommission from and commission to operation of dispatching and technological control and computing facilities.

## 9.6 Testing and Commissioning of New Equipment

**9.6.1. The Dispatch Center dispatchers and Senior operative personnel of electric power plants and electric grids**

- perform operative management of testing in accordance with permitted applications and approved programs, as well as commissioning of new equipment, relay protection facilities and automatic equipment to operation.

## 9.7 Transmission of Operative Information and Operative Reporting.

**9.7.1. The Dispatch Center dispatchers and Senior operative personnel of electric power plants and electric grids:**

- receive from the subordinate operative personnel massages about violations of the regime, accidents with people and other events;
- submit the corresponding information to superior operative personnel in accordance with the established order;
- keep operative reporting, indicating all significant deviations from the given schedule;

- provide recording of operative conversations.

# 10. Prevention and Elimination of Emergencies

## 10.1 General Provisions

### 10.1.1. Main directions

Main directions for failure prevention and emergency operations in the Grid can be found in the "Standard Instructions for Failure Prevention and Emergency Operations in Transmission Networks of Power Systems", 1992, ORGRES, Moscow.

### 10.1.2. Emergency operations

Emergency operation of the 330-kV interconnections will be controlled by the Ukrainian UPS operator, with the exception of the Kotovsk-Rybnitsa 330-kV transmission lines, where emergency operations will be directed by the Moldenergo Central Dispatch operator, and the MGRES-Artsyz 330-kV line, where emergency operations will be controlled by the Odessaenergo dispatcher.

Emergency operation of the 110-kV interconnections with Vinnitsaenergo and Odessaenergo shall be conducted in accordance with the instructions on interaction between the dispatch operators of Moldenergo, Vinnitsaenergo and Odessaenergo.

### 10.1.3. Dispatch

The Moldavian EPG Dispatcher will control emergency operation in the following cases:

- system outages with concomitant frequency and voltage deviations, disturbances in operating conditions of the 110-400-kV backbone transmission lines and system interconnections, asynchronous operations and a power system collapse;
- emergencies caused by outages in the 330-kV backbone network;
- emergencies caused by outages in the primary network of power plants and 330-400-kV substations;
- emergencies caused by outages in the 110-kV network comprising substations of different enterprises.

### 10.1.4.

Distribution of responsibilities among operator personnel in emergency operation of any other equipment of the power system shall be determined by local instructions.

### 10.1.5.

All local instructions for failure prevention and emergency operation of transmission facilities in the Moldavian power system shall be in conformity with these instructions.

## 10.2 Low Frequency Emergency Operations

**10.2.1.**
Frequency control will be the responsibility of the Ukrainian NDC Operator.

**10.2.2.**
In case of a sudden frequency drop by 0.1 Hz from a set value, the Central Dispatch operator will mobilize reserve capacity in order to maintain a set value of net power flows with frequency correction. The magnitude of correction is 100 MW/Hz.

**10.2.3.**
During a load rise the MGRES personnel must control load in the outgoing 330-400-kV lines to prevent their overloading above the allowable stability value for normal and maintenance conditions or above the allowable emergency current load for actual temperatures of outdoor air.

Any changes in the MGRES load and achieved limit loads of the outgoing power lines must be immediately reported to the Central Dispatch operator.

**10.2.4.**
In case of a sudden frequency drop below 49.5 Hz:

10.2.4.1. The Central Dispatch operator must ensure speedy loading of power plants subject to load monitoring in the backbone transmission lines and interconnection ties.

10.2.4.2. In case of insufficient capacity and a continuous frequency decrease, the Central Dispatch operator must immediately, within 10 minutes, disconnect customers by 6-10-kV lines, with load monitoring in system interconnections, subject to maintaining specified net power flows with frequency correction.

10.2.4.3. The operating personnel of MGRES, KTEC-1, KTEC-2 and BTEC must check whether the actuator valves of turbines are open according to the constant-error response and speed up the boilers to maintain normal steam conditions.

10.2.4.4. Customers who were disconnected manually or through automatic frequency load shedding [AFLS] (if they were not reconnected by frequency-actuated automatic reclosing [FAAR]) can be reconnected, with the Central Dispatch operator's permission, when frequency rises above 49.5 Hz, subject to specified net power flows with frequency correction. The reconnected customer load depends on a generation increase in the power system.

In case of emergencies with a steep frequency decrease, the Central Dispatch operator should take into consideration that demand of customers connected to AFLS accounts for 60% of the total power system demand. Fifty per cent of these customers are connected to frequency-actuated automatic reclosers at unmanned 110-kV substations.

For speedy customer reconnection by FAAR, the Central Dispatch operator, jointly with the dispatchers of other power systems, should take measures to increase frequency by 0.1-0.2 Hz above a set FAAR value. Take note that most of the automatic reclosers operate in a frequency range of 49.5-50.0 Hz.

**10.2.5.**
Actions of the operating personnel in case of a frequency drop and separation of the Moldavian power system from the interconnection:

10.2.5.1. If the Moldavian power system, fully or in part, separates from the UPS of Ukraine with a steep frequency drop below 49.5 Hz, the Central Dispatch operator will disconnect customers and take measures to increase frequency for synchronization with the UPS of Ukraine.

Customers will be disconnected through 6-10-kV lines. For the Moldavian power system, the approximate value of customer load to be disconnected in order to achieve a 1-Hz frequency rise is 100 MW.

10.2.5.2. If several power systems, including the Moldavian Grid, are separated from the UPS of Ukraine, the Ukrainian UPS operator will give the disconnection command.

10.2.5.3. If in post-emergency conditions the Moldavian power system operates separately from the interconnection, the Central Dispatch operator must instruct MGRES to control frequency.

## 10.3 High Frequency Emergency Operations

**10.3.1.**
In case of a steep frequency rise above the previously set value, the Central Dispatch operator must identify the cause of the fault.

**10.3.2.**
In case of a sudden frequency rise above 50.1 Hz, the Central Dispatch operator must ensure off-loading of power plants in order to maintain a set value of net power flows with frequency correction. The magnitude of correction is 100 MW/Hz.

**10.3.3.**
The operating personnel of thermal power plants will:

a) check whether the actuator valves of turbines are partly closed according to the constant-error response, with a corresponding capacity decrease;

b) make sure that any actions to maintain the stable functioning of boilers and power units during turbine off-loading are in conformity with the local instructions.

**10.3.4.**
A steep frequency rise may lead to generation shedding at the Dubossarskaya hydro power plant under the action of speed governors and to faulty hydraulic conditions. Therefore, in case of a steep tail-water lowering, the HPP personnel on duty, with the Central Dispatch operator’s permission, must re-load the generators.

**10.3.5.**
In case of a frequency rise up to 50.5 Hz, the operating personnel of MGRES and KTEC-2 (including the personnel of the cubicle control switchboards) must, without waiting for instructions, decrease generating capacity by remote action on the turbine control (in addition to the action of automatic controllers) in order to halt the increase of frequency and to bring it down to 50.2 Hz, controlling power flows in the out-going lines.

**10.3.6.**
When frequency increases to 50.5 Hz or higher, the operating personnel of MGRES and KTEC-2, as per the local instructions, must switch off units with failed control, close the main stop valve and turbine shut-off valves, take boiler protection measures, and report the disturbance to the higher-level operating personnel.

**10.3.7.**
The operating personnel of the power plants must immediately advise the Central Dispatch operator on all their actions to off-load the power plants and on operating conditions of the adjoining transmission lines.

**10.3.8.**
The operating personnel of the power plants must ensure the stable functioning of off-loaded units during the time needed by the Central Dispatch operators to analyze the emergency situations. If need be, the power plant personnel can re-distribute load among the generators at their own discretion.

**10.3.9.**
When off-loading the power plants, the personnel must ensure the availability of equipment for immediate loading at the Central Dispatch operator’s command in case of insufficient capacity and a frequency drop.

**10.3.10.**
In case of the Moldavian power system’s separation following a frequency rise, emergency operations will be controlled by the Central Dispatch operator. In case of several power systems’ separation from the interconnection with the UPS of Ukraine, emergency operations will be controlled by the Ukrainian UPS operator.

**10.3.11.**
If the power system separates from the UPS of Ukraine, the Central Dispatch operator must take measures for synchronization and restoration of parallel operation.

## 10.4 Voltage Drop

**10.4.1.**
Dangerous voltage drops may occur in cases of insufficient active and reactive power in the power system, when 330-400-kV interconnection ties carry a heavy load in controlled sections.

A voltage drop may cause disruption to customers' operations or disturb stability of 330-400-kV interconnection ties.

**10.4.2.**
The 330-kV buses of MRGES, which most of the plant units are switched to, are the power system's major node that ensures steady-state stability of system interconnections. The minimal allowable long-term voltage for steady-state stability at these buses is 330 kV. The emergency limit of lower voltage, which may lead to disturbance of steady-state stability and to asynchronous conditions in case of overloads in the Ukrainian UPS' 330-kV interconnections with the power systems of Odessa and Moldova, is 300 kV.

**10.4.3.**
The minimal allowable long-term voltage for customer load stability in the control points on the Moldavian power system is as follows:

for the Kishineu, Streshen, HBK, Belts, Vulkaneshty and Rybnitsa substations:

110-kV buses – 105 kV.

**10.4.4.**
In case of voltage drops in some of the power system's nodes, the Central Dispatch operator must take measures to increase voltage and, primarily, use reactive power reserves and transformer voltage ratio adjustments.

**10.4.5.**
If the voltage at the 330-kV buses of MGRES goes down below 335 kV because of an overload of the Ukrainian UPS' 330-kV interconnections with the power systems of Moldova and Odessa, the following measures will be taken:

10.4.5.1. The Central Dispatch operator, jointly with the Ukrainian UPS dispatcher, will immediately start off-loading the 330-kV interconnection ties by disconnecting customers in the Moldavian and Ukrainian power systems according to the "Schedule of Emergency

10.4.5.2. The Central Dispatch operator and the MGRES operating personnel will control the re-loading of the MGRES generators.

The operating personnel should bear in mind that a rotor current overload of the MGRES generators is time-limited and is lowered by automatic excitation controllers within a time period determined by the overload factor. If prompt measures are not taken to off-load the interconnection ties, a voltage collapse at the 330-kV buses and stability disturbance may occur.

**10.4.6.**
Customers disconnected through 6-10-kV lines will be reconnected at the Central Dispatch operator’s command after the identification and removal of the causes that led to a voltage drop.

If customers were cut off at the Ukrainian UPS Dispatcher’s command, they will be reconnected only with his permission.

## 10.5 Voltage Rise above the Maximum Permissible Long-Term Voltage Limit

**10.5.1.**
A voltage rise above the maximum permissible limit may occur in the power system in such cases as minimum load operations, one-sided disconnection of 330-400-kV transmission lines, asynchronous conditions and during switching.

**10.5.2.**
According to the Operating Rules R-5.1.16, a short-time (up to 20 minutes) allowable voltage rise must not exceed the following levels:

- for transformers and auto-type transformers – 1.1 of the rated voltage at a specified tap;
- for other equipment:
  - 400-kV lines – 480 kV
  - 330-kV lines – 417 kV
  - 110-kV lines – 145 kV.

**10.5.3.**
In case of a voltage rise above the permissible long-term voltage limit, the Central Dispatch operator must analyze the causes and, jointly with the Ukrainian UPS dispatcher and the power system’s operating personnel, take measures to eliminate the dangerous conditions by the following means:

10.5.3.1. Switching on the reactors at the Vulkaneshty substation and MGRES.

10.5.3.2. Switching off all the 6-10-110-kV lines at the power system’s substations.

10.5.3.3. Off-loading the MGRES and KTEC-2 generators and, if necessary, putting them in underexcitation conditions, as per the local instructions.

10.5.3.4. Lowering voltage at the boundary 330-kV substations of the Ukrainian UPS.

**10.5.4.**
If despite the above measures, voltage at the 330-400-kV buses of any substation is still above the permissible long-term value, the 330-kV lines must be de-energized.

The choice of specific lines to be de-energized depends on operating conditions, schemes, and causes of overvoltage in the power system.

The most frequent reason for overvoltage at the 330-kV buses of the power system's substations is a high voltage level in the night- time at the adjoining 750-330-kV substations of the Ukrainian UPS, particularly on the Dnieper HPP side. In this case, the best solution is switching off the Dnieper HPP-Belts and Belts-Streshen 330-kV lines simultaneously, with the two MGRES-Kishineu 330-kV lines in operation.

When decreasing voltage in the 400-330-kV network, the operating personnel should take into account the action of automatic excitation controllers at the MGRES and KTEC-2 generators, which will be automatically loaded for reactive power in order to maintain voltage at a specified level.

## 10.6 Emergency Operation of 110-400 Transmission Lines

**10.6.1.**
Allowable electric heating loads of 110-400-kV transmission lines in normal and emergency operating conditions are given in the local instructions and tables of allowable current loads for normal and emergency operations.

The operating personnel must not permit transmission line overloads above the allowable emergency values.

If the electric heating overload of a transmission line cannot be reduced to the allowable level, the line is to be de-energized at the Central Dispatch operator's command or, in the absence of communication with the CD operator, by the station or substation operating personnel.

**10.6.2.**
Allowable long-term power flows in the 330-kV interconnections from the UPS of Ukraine to Odessa and Moldova will be determined according to steady-state stability requirements for normal and maintenance operating conditions.

**10.6.3.**
Automatically disconnected 330-400-kV lines will be test-operated with applied voltage and energized as through lines at the Central Dispatch operator's command.

**10.6.4.**
n the event that an area with generating sources separates from the power system, the asynchronous energizing of 110-kV through lines shall not be allowed. They can be energized only by the precision synchronization method under the guidance of the Central Dispatch operator.

**10.6.5.**
An automatically de-energized 110-kV line will be test-operated with applied voltage subject to the following conditions:

10.6.5.1.
The existence of inner electric coupling between all the sections and systems of 110-kV or higher-voltage buses, as well as the on-line operation of all the 330-kV and higher-voltage outgoing lines of a given substation or a power plant.

10.6.5.2.
The absence, before and after disconnection, of current and voltage swings in all the outgoing lines of the power plants or substations where test operation is taking place.

## 10.7 Asynchronous Operation of the Power System

**10.7.1.**
Asynchronous conditions for the 300-400-kV interconnections of the Moldovian power system cannot be allowed even for a short time and, therefore, they must be eliminated by the automatic synchronizing equipment (ASE). If ASE fails to operate, the operating personnel must take measures to detect and eliminate asynchronous conditions.

**10.7.2.**
The symptoms of asynchronous conditions are stable period oscillations of current and power, with current rippling and power changing by quantity and sign.

Simultaneously, there are changes in voltage. The biggest voltage drops occur at the Streshen, Belts and Rybnitsa substations, which are located close to the center of oscillations. Voltage drops at MGRES in asynchronous conditions can be insignificant.

**10.7.3.**
Asynchronous conditions of 110-kV shunt ties will be eliminated by automatic current dividers (ACD).

**10.7.4.**
In case of unceasing asynchronous conditions of 110-kV lines, the operating personnel must de-energize the lines.

## 10.8 Emergency Operation If Moldova's Power System Is Separated From Other Power Systems

**10.8.1.**
If the Moldovan power system separates from the interconnection with other power systems, the priority task for the Central Dispatch operator is to identify the boundaries of separation. One of the signs of the power system's separation is a sharp frequency change. In this case, the Central Dispatch operator must determine the state of the system interconnections and of the points where ASE and ACD are installed and take frequency adjustment measures.

**10.8.2.**
In case of the Moldovan power system's separation, MGRES must be put in parallel operation with the Ukrainian UPS by means of precision synchronization at the 330-kV switch of the Kotovsk transmission line.

If as a result of an emergency the Moldavan power system breaks into two or three parts, it may be convenient to synchronize with the Ukrainian UPS by using the manual synchronizing equipment installed at the 330-kV switches of the Kishineu and Streshen substations. In this case the frequency difference must not exceed 0.1 Hz.

**10.8.3.**
For fast synchronization of the Moldovan power system when it separates with surplus capacity, a short-time frequency decrease will be allowed, but not lower than 49.1 Hz, a value close to the upper limit of AFLS operation.

**10.8.4.**
If the Moldovan power system separates because of insufficient power, which leads to a frequency drop and AFLS operation, immediate measures must taken to increase frequency by mobilizing all reserves and, if necessary, by disconnecting customers.

**10.8.5.**
Restoration of the Moldovan power system's operation in parallel with other power systems can be done only by means of precision synchronization.

In case of synchronization with a synchroscope in emergency situations, the reconnection will be allowed only with a frequency difference of at most 0.5 Hz and without voltage adjustment.

## 10.9 Emergency Operations If Moldova's Power System Collapses

**10.9.1.**
In power system collapse emergencies, the priority task of the Central Dispatch operator is to determine the boundaries of separation, frequency and voltage in the power system and to identify those sections of the system and power plants that have been de-energized. In carrying out the task, the operator will read the precision instruments at the dispatch control center and obtain reports from the personnel of the main power plants and nodal substations.

**10.9.2.**
The operating personnel of power plants and networks will be obliged to:

a) report all the outages, frequency and voltage deviations and equipment overloads to the Central Dispatch operator;
b) take measures to restore frequency and voltage.

**10.9.3.**
On the basis of analysis of the power system operating conditions, the operator must take measures for fast synchronization of the separated parts of the system, using the switches of the power plants and substations equipped with precision synchronization devices.

**10.9.4.**
It is not allowed to energize asynchronously separated areas of the 110-kV network with generating sources, namely KTEC-1, KTEC-2, DHPP, KoHPP, BTEC and in-plant generators of the sugar-mills.

In this case, the manual synchronizing equipment installed at the 330-kV switches of the Kishineu and Streshen substations can be used. for parallel operation restoration. The frequency difference of the separated areas must not exceed 0.3 Hz.

**10.9.5.**
The asynchronous energizing of the Moldovan power system via the 330-400-Kv through lines shall not be allowed.

## 10.10 Emergency Operations If Moldova's Power System Is Separated From Other Systems with Complete Voltage Loss and Total Outage of MGRES

**10.10.1.**
Actions of the Central Dispatch operators and the MGRES operating personnel must be primarily aimed at restoring auxiliary power supply of MGRES, other power plants and 330-400-Kv substations and power supply to the most important customers.

**10.10.2.**
During black start operations, the operating personnel shall be guided by the following considerations:

- the volume of connected customer load must correspond to the loading rate of MGRES units in a post-emergency state;
- frequency and load flows control in a restorative working state will be carried out by the MGRES operating personnel;
- when energizing the de-energized sections of the network, the personnel must take into consideration that the customer load does not grow instantaneously, but within minutes;
- as the system restores, the Central Dispatch operator must synchronize all the power plants with the power system and start parallel operation with other power systems;
- procedures for supplying power from the MGRES buses to the de-energized sections of the system will be determined by the post-emergency network scheme and by the existence of communication with the power system facilities;
- the duty personnel of the de-energized power plants and substations will not switch off anything, except for damaged equipment;
- frequency changes during MGRES loading may trigger automatic frequency load shedding and frequency-actuated reclosing equipment.

# 11. CAPACITY RESERVES

The emergency reserve is realized within 10 minutes.

The regulating reserve of capacity contains two to three components. The first one is a so-called primary reserve, which is realized by action of the automatic regulators of rotation rate (ARRR) installed at each generating unit. Operating units’ loads are changed under the impact of ARRR with increase or decrease of frequency, trying to restore the normal frequency in the EPG. The more the generating units that participate in “primary” regulation of the frequency, the less is its deviation from the normal value. The reserve shall comprise 2.5% of a total available capacity of operating units.

The secondary regulating reserve is the reserve of capacity to be realized by actions of centralized facilities of automatic regulation of frequency and real power (AFRP), which are set up at the Dispatch Center of the EPG Dispatch Center. The task of the secondary regulation of frequency is restoration of balance-transfers of the EPG true power in accordance with the dispatching schedule and prevention of dangerous overloading of basic electric power lines controlled by means of the AFRP, which can occur in the result of ARRR local facilities operation.

In some cases the tertiary reserve, which is a real power reserve realized automatically or manually by the operative personnel to release the secondary reserve used earlier to restore the normal values of frequency and real power transfers, is used.

A total value of secondary reserve (which is realized within approximately 5 min) and tertiary (within 30 min) shall be 2.5% of a total available capacity of units involved into operation.

Thus it is necessary:

- To have ARRR at your units and capacity reserve for its efficient operation;
- To have capacity reserve at operating units, this is necessary to carry out secondary and tertiary regulation of frequency;
- To have emergency reserve of capacity;
- To have reactive power reserve and regulating facilities; this is necessary to maintain voltage at the control points of the basic grid when hardened or emergency regimes occur.

Operative reserves and preservation of regime in frequency and real power. Preservation of the normal regime of operation requires availability of two basic types of real power operative reserves:

- Emergency (for prevention of dangerous frequency drop and restoration of its normal value if the generating capacity is out of order accidentally); and
- Regulating (to maintain the installed value of frequency in the normal operation regime).

The basic type of reserve, which shall be provided, serves as emergency reserve to compensate for possible sudden loss of the largest unit.

The higher value of two power values, a total regulating and an emergency ones, is considered as decisive one.

All operating units shall participate in regulation of frequency through capacity changes under the effect of turbine's regulation systems within the set regulating range, i. e., carrying out primary regulation. It is also necessary to include TEPP's units, together with HPPs, in secondary regulation under the effect of centralized regulators of frequency and real power. This will allow regulating the EPG regime in frequency and real power more efficiently.